Offshore Wind Energy and Civil Engineering in Germany – A Green and Sustainable Partnership

Carsten Ahrens
Jade-Hochschule, Zentralverband Deutscher Bauingenieure (ZDI), Germany
World Council of Civil Engineers (WCCE), Spain

Abstract

The contribution of wind power plants to green and sustainable energy is increasing rapidly worldwide. More and more wind power plants in Germany "go offshore". Some German construction companies go offshore, too. Their involvement in the offshore energy sector is to do normal civil engineering work like piling down the fundament tubes. But economical and ecological reasons demand a new method, which takes into account rough soil conditions and the unbearable acoustic impact on marine mammals. This new method is a vertical shaft drilling method and will be brought into the offshore energy market by the German companies Hochtief and Herrenknecht.

Introduction – European Background

In spring 2010, European and international climate experts at PwC, the Potsdam Institute for Climate Impact Research and the International Institute for Applied System Analysis published 100% Renewable Electricity – A roadmap to 2050 for Europe and North Africa. The report examined the potential for powering Europe and North Africa with renewable electricity exclusively by 2050. It set out a serious of financial, market, infrastructure and government policy steps that would need to occur if such a ‚what if' vision was to be achieved [1].

The European Wind Energy Association (EWEA) published in its latest reports, see also table 1:

Till 29 November 2011 over 141 gigawatts (GW) of offshore wind energy capacity is built, under construction, consented, or planned in Europe: enough to power 130 million average EU households. These wind farms - representing 35 times more capacity than the just under 4 GW installed today - would provide 13.1% of Europe's total electricity production.

EWEA has been analysing all existing offshore wind power projects in 17 EU member states, mostly in north-western Europe. New offshore wind farms with a capacity of 5.6 GW are currently under construction in the UK, Germany and Belgium. It estimates that offshore wind energy offers the growth and jobs that Europe desperately needs.169,000 jobs in the EU offshore wind energy sector are expected to be created by 2020, going up to 300,000 by 2030, according to the EWEA report.

The wind energy sector's contribution to GDP till 2020 will have increased almost three-fold. If the industry were a Member State, it would rank 19th in 2020 in terms of its contribution to EU GDP, above Slovakia and just below Hungary, and the number of jobs will go up by over 200% to reach 520,000 by then, says the report.

European companies are currently global leaders, with over 99% of the world's installed offshore capacity in European waters. Areas for growth in offshore wind energy include turbine and turbine component manufacturing as well as substructures, vessels, electrical infrastructure including high voltage subsea cables, and ports.

However, the new report warns that if the offshore wind energy sector's potential is to be fulfilled in Europe, it is imperative that

	Online	Under construction	Consented	Planned	Total projects	Size of government concession zones or foreseen future tender zones
Belgium	195	462	750	450	**1,857**	2,000
Denmark	854	0	418	1,200	**2,471**	4,600
Finland	26	0	765	3,502	**4,294**	n/a
Estonia	0	0	1,000	0	**1,000**	n/a
France	0	0	0	6,000	**6,000**	6,000
Germany	195	833	8,725	21,493	**31,247**	8,000
Greece	0	0	0	4,889	**4,889**	n/a
Ireland	25	0	1,600	2,155	**3,780**	n/a
Italy	0	0	162	2,538	**2,700**	n/a
Latvia	0	0	200	0	**200**	n/a
Malta	0	0	0	95	**95**	95
Netherlands	247	0	1,792	3,953	**5,992**	6,000
Norway	2	0	350	11,042	**11,394**	n/a
Poland	0	0	0	900	**900**	n/a
Portugal	0	0	0	478	**478**	n/a
Spain	0	0	0	6,804	**6,804**	n/a
Sweden	164	0	991	7,124	**8,279**	n/a
UK	1,586	4,308	588	42,114	**48,596**	47,000
Total Europe	**3,294**	**5,603**	**17,341**	**114,737**	**140,976**	**73,695**

Table 1: Offshore wind power generators in Europe (online, under construction, consented, planned)

sufficient levels of financing are brought in by
investors. Also crucial are the financing and building of offshore power grids in the northern and Baltic seas, which would enable huge amounts of electricity to be transported to consumers. For the industry itself, there is a risk of a high-voltage subsea cable shortage in the next few years which has to be addressed urgently, says the report, as well as a possible shortage of trained workers. "The offshore wind energy sector can replicate the success of the onshore wind technology development, which is now a mainstream source of power competitive with new coal and gas plants, and a major European industry", said Zervos. "However, to ensure this happens, EU-decision-makers need to set ambitious renewable energy targets beyond 2020, invest more in research and develop offshore grid".

Future Development and Status in Germany

“We are becoming more and more aware of the climate change that we humans have caused. At the same time, we are worried about the security of our energy supply. For this reason, we must make our energy supply viable for the future and place greater emphasis on energy efficiency and renewable energies.

Therefore, with the Renewable Energy Sources Act the Federal Government is pursuing the goal of generating at least 12.5 % of Germany's electricity needs from renewables by 2010, and at least 20 % by 2020.

To achieve this goal, the enormous potential of offshore wind power generation must be tapped. The aim is to construct offshore wind parks with a total capacity of 20,000 - 25,000 megawatt in the North and Baltic Seas by 2030. These can cover around 15 % of Germany's electricity needs.

Fig. 1: Offshore wind power development in Germany [4]

This would give rise to a highly innovative branch of industry, which would create jobs especially in the coastal federal Länder. It would also enable us to reduce Germany's dependence on energy imports and keep electricity prices under control.

I am convinced that offshore wind energy will thus become a major pillar of energy supply in the 21st century”, see figure 1. These words are given by S. Gabriel, former German Environment Minister [4].

The political statement and possible wishes are underpinned by the actual status and the detailed prognosis for the offshore wind power development as described in table 2 respectively figure 2 [2].

Installed	No of WEA	Power [MW]
Total Germany	55	215,3
North Sea	33	164,5
Baltic Sea	22	50,8
under construction	ca. 140	700
Planned		up to 40.000

Table 2: Status in Germany April 2012 [2]

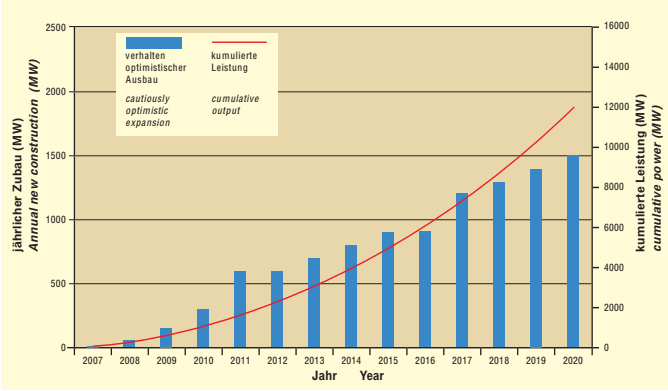

Fig. 2: Forcasted expansion of offshore wind power Generators (WEA) – cautiously optimistic expansion according to Deutsche WindGuard [5]

The priority of offshore wind power generation is clearly described in figure 3, as it compares on- and offshore power generation till the year 2030. Whereas onshore wind power remains stable at a high level, offshore wind energy increases rather rapidly [5].

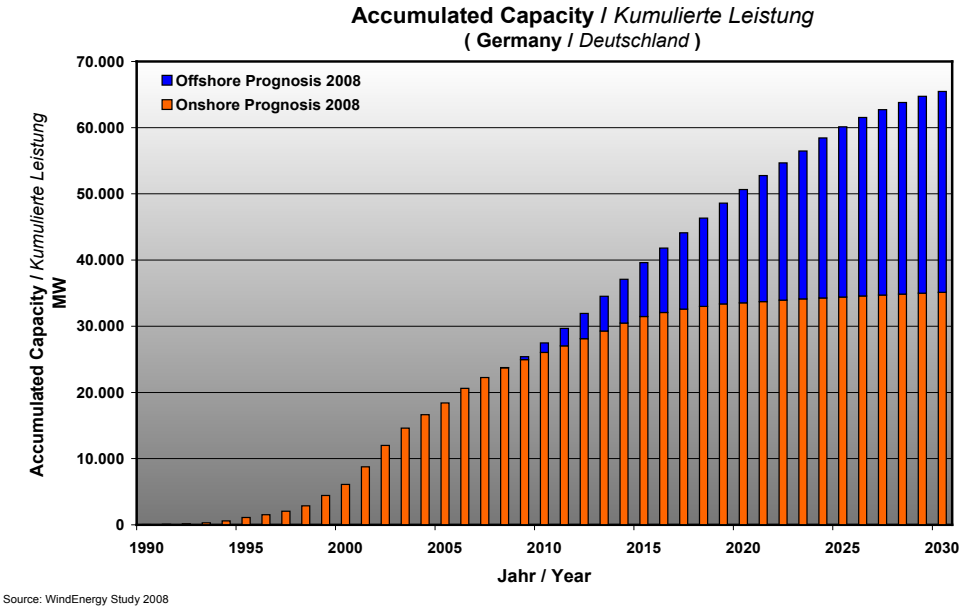

Fig. 3: Accumulated on- and offshore capacity [6]

Connection to Grid

In future a significant proportion of Germany's wind energy will come from offshore wind farms in the North Sea, see figure 4, and the Baltic Sea. These farms have to be connected to the land-based power grid. According to the dena Grid Study II [5] different electric connections, including cluster connections, see figure 5, have to be taken into account.

Fig. 4: Wind farm

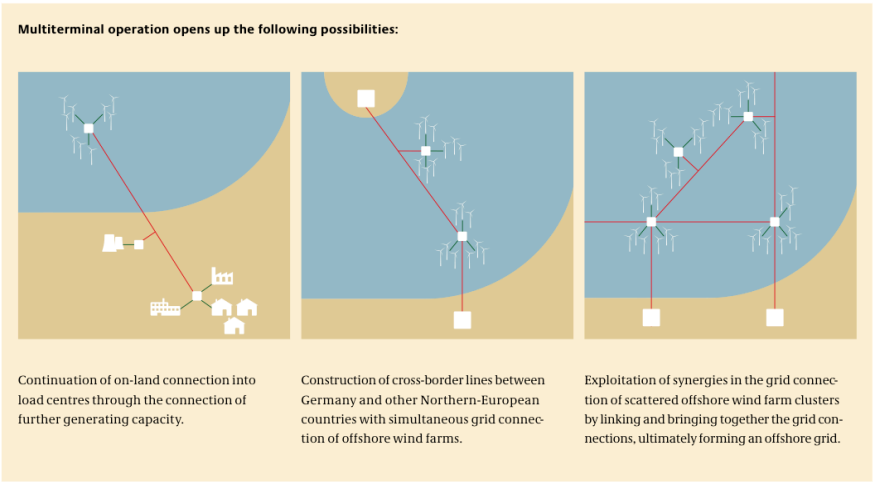

Fig. 5: Connection of wind farms to to the land grid

To connect the wind farms to the land grid, by 2020 marine cables extending to a total length of about 1,550 km are needed, resulting in annual costs of 340 million €. The cumulative cost are given in figure 6 [3].

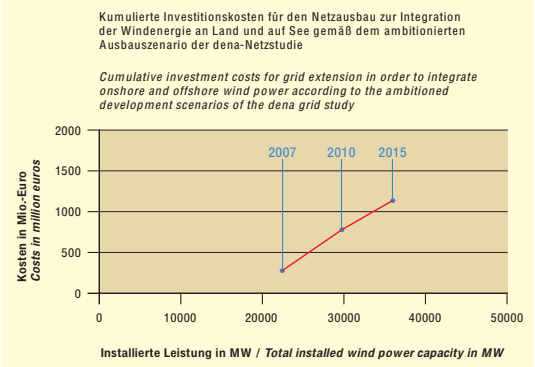

Fig. 6: Cumulative investments for grid extension

The further expansion of wind energy in Germany will reduce relative regional fluctuations and a higher availability of the Germany-wide electricity feed-in from wind energy will be reached.

In accordance to table 1 it is clear that Germany is just one of the many “European wind farmers”. Therefore it is reasonable to connect these wind farms with a so called supergrid in Europe and, thus, opens the electricity market within Europe.

The “friends of the supergrid” [7] are much emphasising such a grid to balance regional shortages and/or overproduction of electric energy. This project includes all kind of renewable energy and could include in a later phase also North Africa.

Figure 1: Supergrid Phase 1

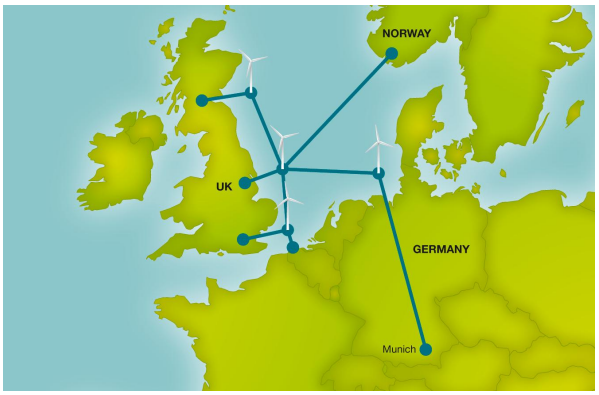

Fig. 7: The European supergrid Phase 1

Involvement of Hochtief as a Civil Engineering Company

Under the motto “Civil Engineering and Marine Works” the internationally active building company Hochtief is very much engaged in offshore wind power plants. By this Hochtief offers normal civil engineering know-how and work in soil investigation, piling of tubes as tower fundaments, marine logistics, but also comes up as a ship owner. This is “competence far from the coast”, as one of the advertising papers is describing this new business segment [10].

Figure 8 is showing that the spectrum of engagement covers all topics as described earlier. Even laying see cables is a new work of this – old and settled - civil engineering company [10].

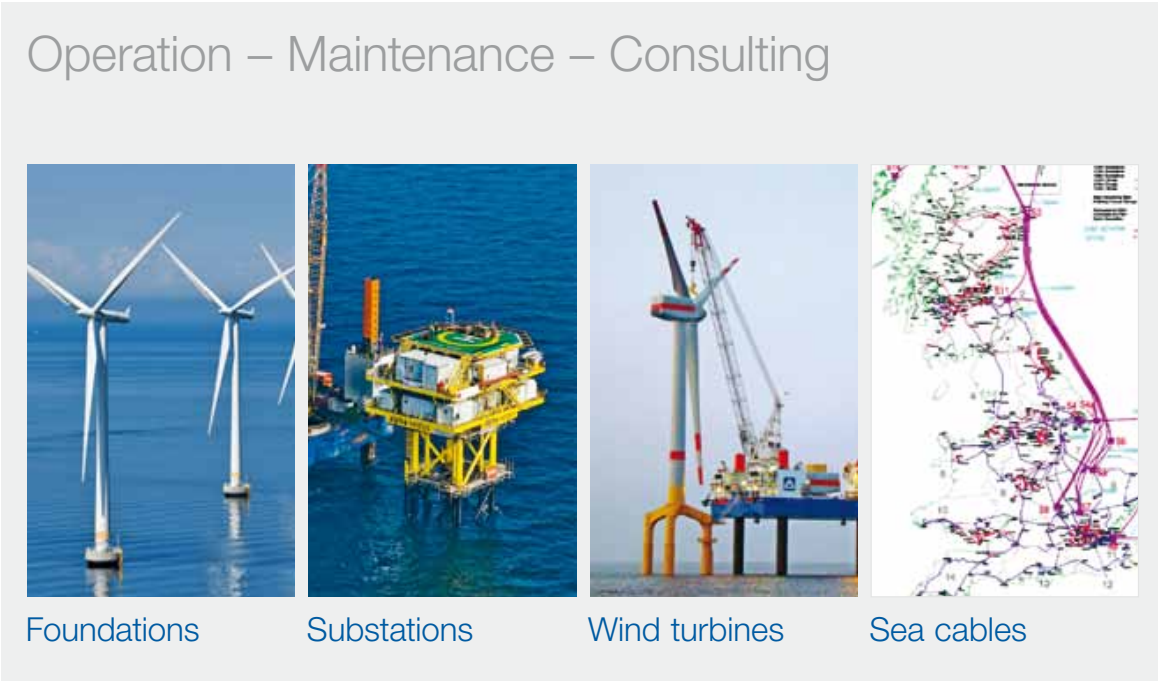

Fig. 8: Involvement of Hochtief as a civil engineering company at high seas [10]

The offshore market is booming. In mid-2012 the first jack-up vessel will be launched for implementing large-scale wind farms: far away from the coasts, in deep waters and operating big turbines. From 2012 more than 800 wind power plants will be installed each year in Europe, and 80% of these will be set up more than 50 kilometres from the coast. The majority of the projects are to built in water depths from 35 to 50 meters. Because the power of the turbines becomes bigger and bigger (more than 6.5 MW) the foundation structures of the wind generator towers have to be adequately strong.

With the offshore jack-up platform Odin, HOCHTIEF has had its own specialized equipment available since 2004. In 2010, the jack-up vessel Thor was added. From the beginning, HOCHTIEF Solutions has assembled its own offshore crew, from deckhands to captains. Since 2010, HOCHTIEF Offshore Crewing GmbH has been responsible for recruiting. In partnership with IG BAU, the pioneering company has introduced its own in-house collective agreement for its crew. “Our crew has many years of experience and expertise in services for wind power plants at sea and offers a sound level of education and training. In addition to professional qualifications, it is qualified to carry out any crew change by helicopter or to provide medical care or fire fighting services”.

Out on the open sea near Borkum Hochtief was involved in the installation of the first German offshore wind farm Alpha Ventus. It completed the soil investigation and built the transformer station and half of the twelve foundations with its own jack-up platform ODIN, see figure 9.

In Öresund, seven kilometres off the Swedish coast near Malmö, Hochtief manufactured and transported 48 heavy weight foundations, see figure 10.

In the Bard Offshore 1 field Hochtief piled down the so called tri-piles with its own heavy lift platform Thor, see figure 11.

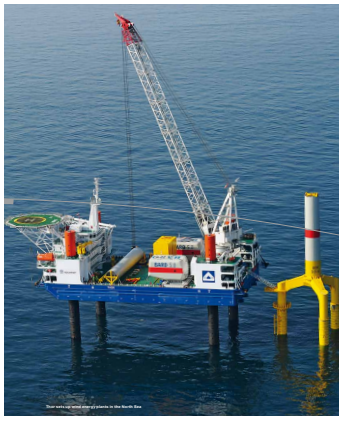

Fig. 9: Farm Alpha Ventus Fig. 10: Lillgrund close to Malmö Fig. 11: Thor at Bard Offshore 1

Hochtief Offshore Solutions offers a tailor-made maintenance strategy for wind power plants. This combines logistic, constructional and service measures in an early project phase, includes also regular inspection and repair routines, for example for foundation structures, substations and sea cables.

Offshore Foundation Drilling (FOD) by Herrenknecht

Up to now Herrenknecht was one – or is now - of the world leaders in horizontal drilling techniques. All over the world big tunnel projects for railways, underground trains, express highways, water flow etc. have been built by Herrenknecht. The last development in drilling started with the so called vertical shaft machine technique by which numerous shafts for underground stations, parking towers, water distribution and inspection [11].

“In partnership with Herrenknecht AG, HOCHTIEF Solutions has developed a more efficient and, most of all, more environmentally friendly way of emplacing wind turbine foundations.” So far the citation of Hochtief.

By this technique, called **offshore foundation drilling**, foundation structures for wind turbines are anchored to the sea floor by a drilling process. This method is highly adaptable, thus, offshore foundation drilling opens up various other technical options, such as drilling pile diameters bigger than the six meters that mark the limit for conventional pile driving.

HOCHTIEF SOLUTIONS AG

Offshore Foundation Drilling

Herrenknecht started a feasibility study from 2007 – 09 together with the Technical University Hamburg-Harburg TUHH) and the Institute for Applied Physics (ITAP), Oldenburg [12]. The study concerned the technical stability of the foundation, its economical feasibility - and the noise reduction.

The next step forward took place with Hochtief to develop the complete concept, especially with respect to the detailed drilling procedure and necessary ship support. In 2012 an electricity company (EnBW) joined the consortium. A prototype of the offshore drilling machine has been installed, tests have been made for certification. Additional scientific guidance and monitoring has been agreed upon.

This new drilling device offers the possibility to bring down huge foundations, where the normal piling method fails. And it can successfully work also in gravel and clay sea beds.

But the most ecological and future oriented advantage of this technique is its noise reduction of the foundation process to a very low sound pressure level.

The resulting underwater noise pressure of normal piling processes can seriously harm marine fauna, especially harbour porpoises – not only in the German North Sea and Baltic Sea.

Fig. 12: Sea bed and animals

The advantages of the offshore foundation drilling method are obvious. Huge foundation from 4 to 7 m in diameter - and possibly more - can be brought to the sea bed as they are used for monopole wind power towers. The new system on the other hand and with another drilling device can drill also smaller tube foundations e.g. for tri-piles or tri-pods, which have diameters of 2 - 3 m, as figures 13 and 14 show.

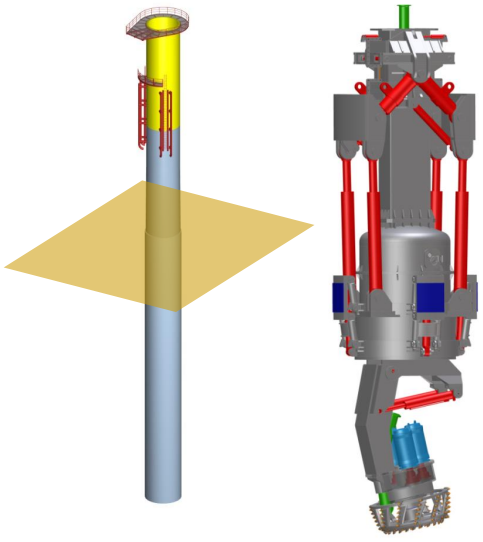

Fig. 13: Large Scale drilling Technique (OFD-LD) for monopole foundation

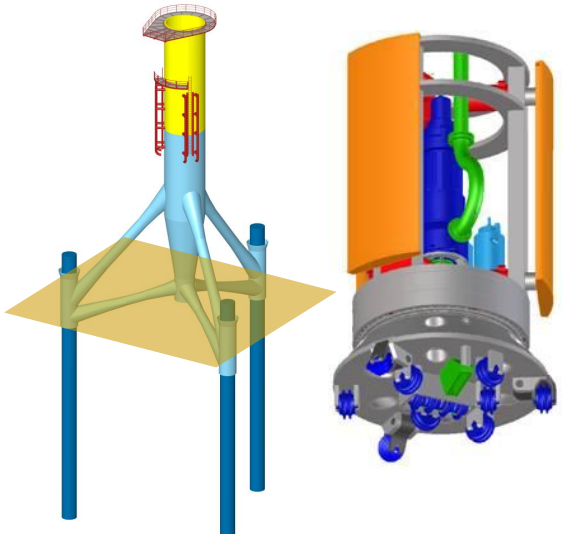

Fig. 14: Small Scale Drilling Device (OFD-SD) for dissolved structures

Ecological Impact and Sound Reduction

The greatest problem connected with the foundation of wind power towers is the great noise impact onto the sea mammals, especially porpoises. The sound pressure reaches values of up to 190 dB in a distance of 750 m from the piling process. Due to German law as published by the German Federal Water Authority (BSH) only 160 dB are allowed in that distance. So, each of the German wind power generators have been built “out of law”.

As this is a specific German issue, there are currently no effective measures for the reduction of impact noise that might be integrated into complex installation logistics. In other European countries, where large numbers of offshore wind farms have already been built, the relevant licensing authorities simply require applicants to ensure that sea mammals are kept temporarily at a distance. Using sonar buoys – so-called pingers – acoustic signals are emitted before the installation of the foundation, ensuring that sea mammals are kept at bay. Whale watchers then monitor the area around the construction project and provide feedback on the effectiveness of the pingers. Mory reover, during the piling process, a “soft start” ensures that fish and porpoises are kept at a distance from the project area.

Huge efforts have to be done to reduce the noise. At the very first installation Fino 3 a cylindrical curtain of air bubbles has been installed – with relative poor results, see figure 15. Another trial to reduce the piling noise is shown in figure 16. A huge (hand sewn) cylindrical bubble curtain is pulled around the piling hammer and foundation [13]. The proud information as given on the advertising paper talks about 50% noise reduction. This sounds quite a lot, only half of the noise. But as the sound is measured in a logarithmic scale one half is only a reduction of just 3 dB. So, from e.g. 180 dB the value goes slightly down to 177 dB, which seems to be really nothing.


Luftbild vom Blasenschleier zur Schallminderung um die Baustelle der Forschungsplattform Fino 3

Fig. 15: Air bubbles around platform Fino 3

Fig. 16: Air bubble curtain around pile [13]

A research programme for the evaluation of systems for the reduction of piling noise (ESRA) [3] is planned to be launched in cooperation with eight builders of German offshore wind farms. The purpose is to protect porpoises during the building phase and thus to ensure the unhindered construction of offshore wind farms. On 17th May 2011, eight builders and operators of German offshore wind farms have concluded this joint venture agreement under the umbrella of the German Offshore Wind Foundation. The aim is to research and develop the efficiency of various noise reduction methods in the construction of offshore wind farms.

One special feature of this project is the inclusion of the greatest possible number of German offshore planners and operators to make the benefits accessible to the entire German offshore industry. Having analysed the readings, the joint venture partners will provide all project partners with the final report, which will include their recommendations for each of the technologies. This will also benefit licensing authorities and manufacturers of noise protection systems. Numerous workshops will be held, explaining the results and discussing the further procedure.

Herrenknecht in co-operation with Hochtief will have the “best cards” with its new offshore foundation drilling technique. Figure 17 shows the different sound measures according to the different methods or law respectively. The data are taken or calculated for a distance of 750 m. The thick red bar describes the continuous sound level during piling, the value is between 165 and 175 dB. The blue line represents the value of 160 dB as fixed by BSH. Far below, namely more than 40 dB, lies the value of noise as generated by the new offshore foundation drilling method of Herrenknecht. – The description is in German language: Schalldruckpegel – sound level, Dauerschall – continuous sound, Grenzwert – limit of measures, Bohren – drilling, Rammen – piling, Schalldruck [Pa] (logarithmisch – sound pressure [Pa] (logarithmic), Unterschreitung – sound pressure difference below blue level.

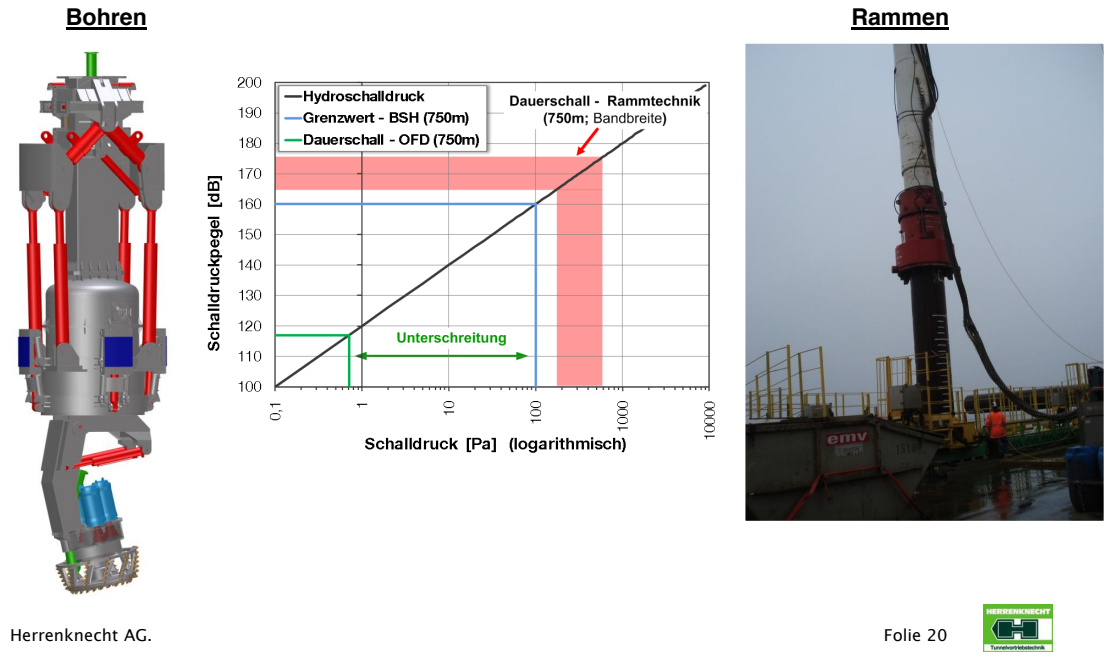

Fig. 17: Sound level measures OFD (green) – BSH-value (blue) – piling (red)

Summary

Offshore wind power is one of the strong green energies of the future in Germany. Foundation works for the wind power generators, marine logistics service, laying down sea cables and building onshore cable networks are new, very interesting and future oriented work fields of the German companies Hochtief and Herrenknect as members of the civil engineering world.

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Einsatz der OFFSHORE FOUNDATION DRILLING MACHINE (OFD®) im Bereich der Errichtung von Offshore-Windenergieanlagen.

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